

Design and construction of a 200 TW laser compressor chamber for the Pulsed Laser Center, CLPU facility at Salamanca

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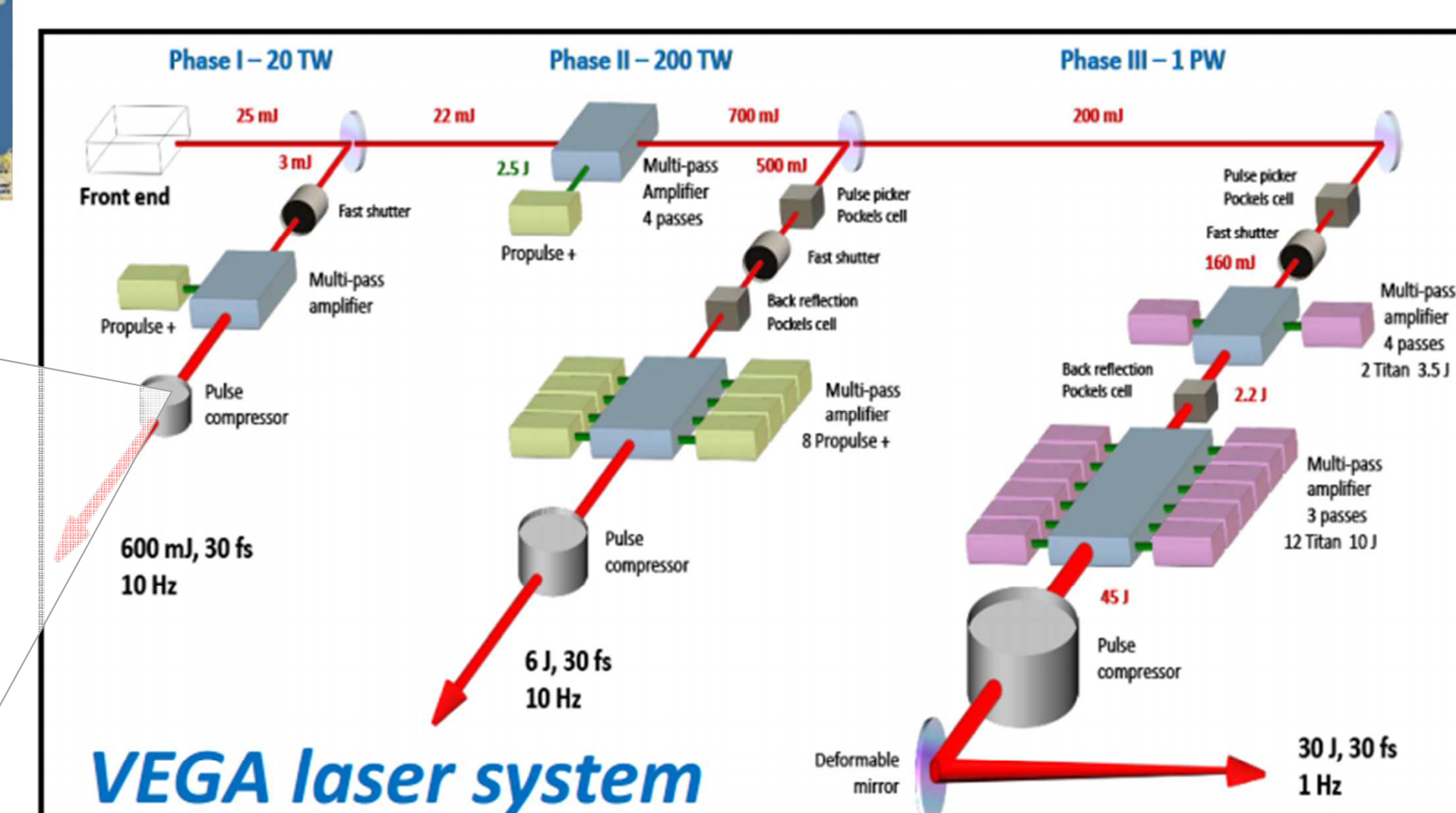
Abstract

The Pulsed Laser Center (Centro de Láseres Pulsados, CLPU) is a facility specialized in femtosecond laser pulses with peak powers at Gigawatt, Terawatt and Petawatt levels. The new facility will offer a ladder of laser pulses for different applications: 20TW, 200TW & 1 PW. The facility requires the design and construction of much new optical equipment including the vacuum and mechanical components. One of the critical elements is the compressor and its vacuum system, chamber, and mechanical support. In this article the design of the a new 200 TW laser compressor chamber is presented from the specification requirements up to the final results at site delivery at CLPU Salamanca within the framework collaboration between ALBA – CELLS and CLPU. In this new design all the optical components are mounted on a thick stable breadboard which defines a single flat reference plane for all of them and supported by a robust leveling system based on four columns including a preloaded kinematical mount which reaches stabilities better than 60 nm under vibration behavior. The entire models and FEA calculations accomplish with the specifications and the final measured results match the expected figures achieving a vacuum level below $6 \cdot 10^{-7}$ mbar and pumping time less than 10 hours after the chamber enclosure. Parts of this design has been patented, patent application number U201431357.

Precedents

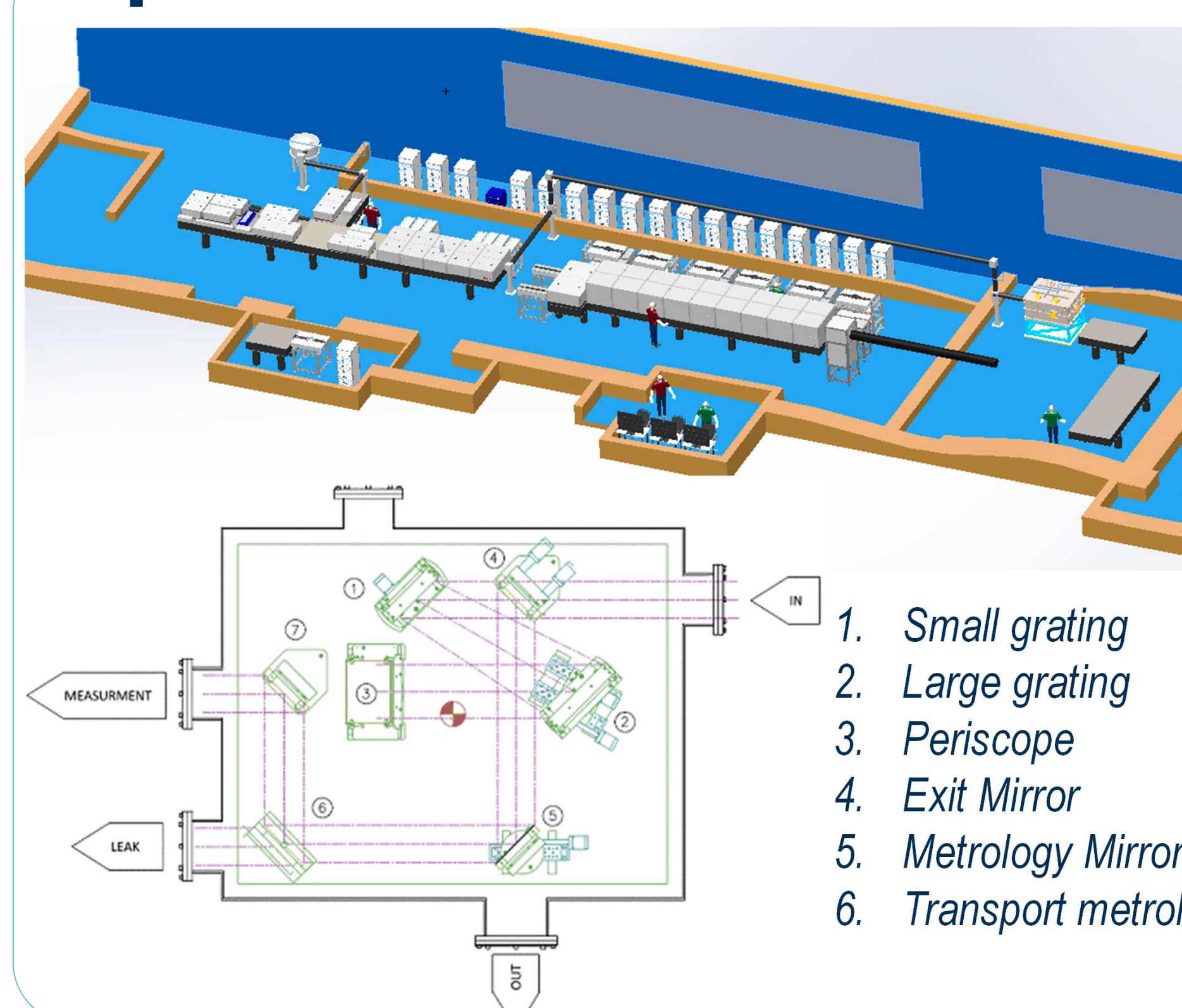


- Phase I – 20 TW (600 mJ / 30 fs), 10 Hz
- Phase II – 200 TW (6 J / 30 fs), 10 Hz
- Phase III – 1 PW (30 J / 30 fs), 1 Hz



Three outputs are fully synchronised - Allows pump and probe

Specifications



Specifications summary

Characteristic	Performance
Vacuum level	$1 \cdot 10^{-6}$ mbar
Pumping time	10 h (up to $5 \cdot 10^{-6}$ mbar)
Mechanical stability	$< 1 \mu\text{m}$
Breadboard leveling resolution angular	$30 \mu\text{rad}$
Breadboard leveling resolution linear	$50 \mu\text{m}$
Breadboard flatness	$50 \mu\text{m}$
Viewport angular deviation	$< 10 \text{ mrad}$

Basic design

The system is composed by two main functionalities:

- Vacuum enclosure:
 - Vacuum level
 - Vacuum pump down time
 - Vacuum chamber
- Mechanics, optics reference breadboard:
 - Stable Breadboard
 - Stiff Breadboard leveling system
 - Optics reference surface support, breadboard, independent from vacuum chamber support:
 - Vacuum Chamber support is steel frame
 - Breadboard support is a massive granite block.

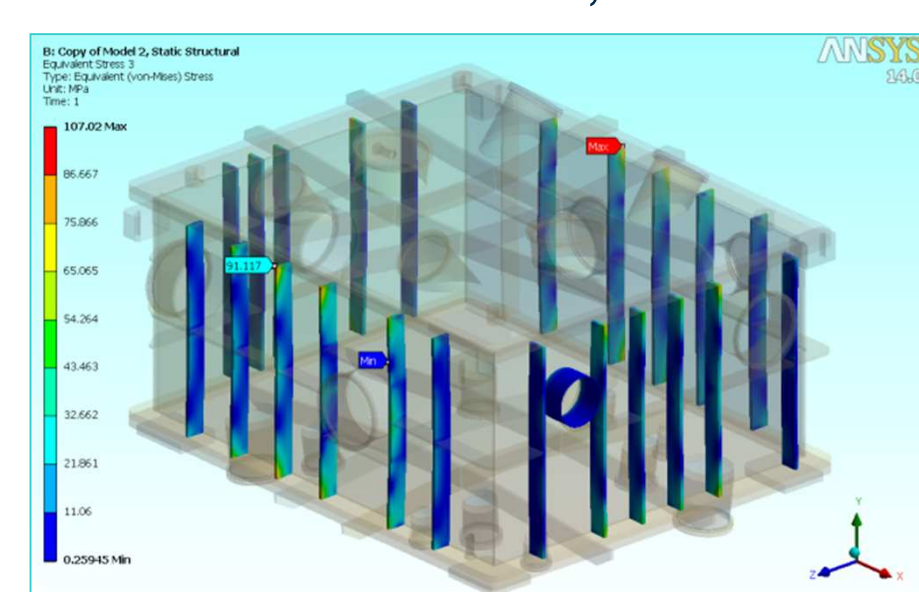
Moreover the market does not have such diameter viewport with borosilicate thus a customized sealing viewport holder must be designed.

- Windows:
 - Viewport: double O-Ring sealing holder, manually adjustable

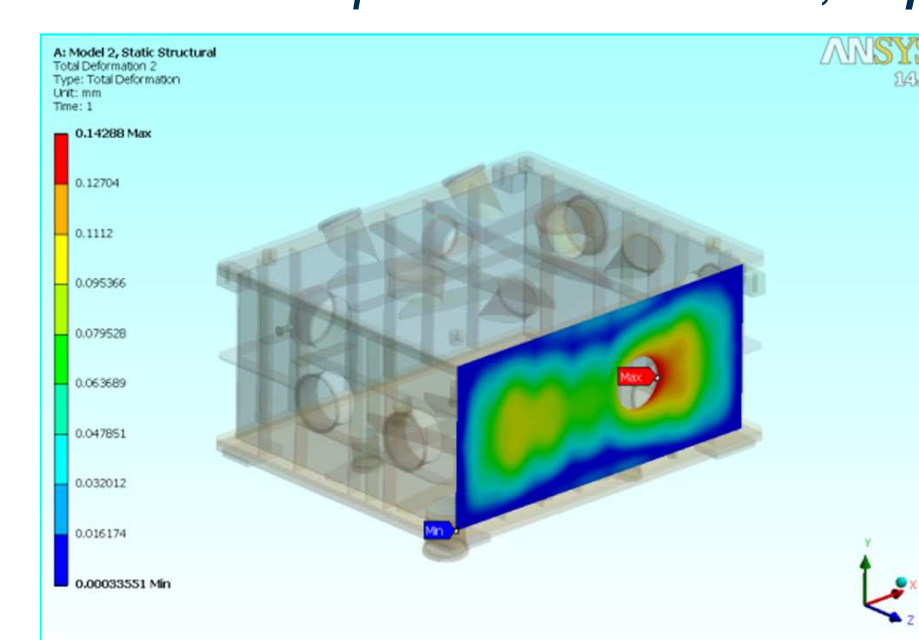
Design

Vacuum chamber

- Rectangular design for space minimization
- Maximum stress: 107 MPa
- Maximum deformation 0,99 mm on top cover

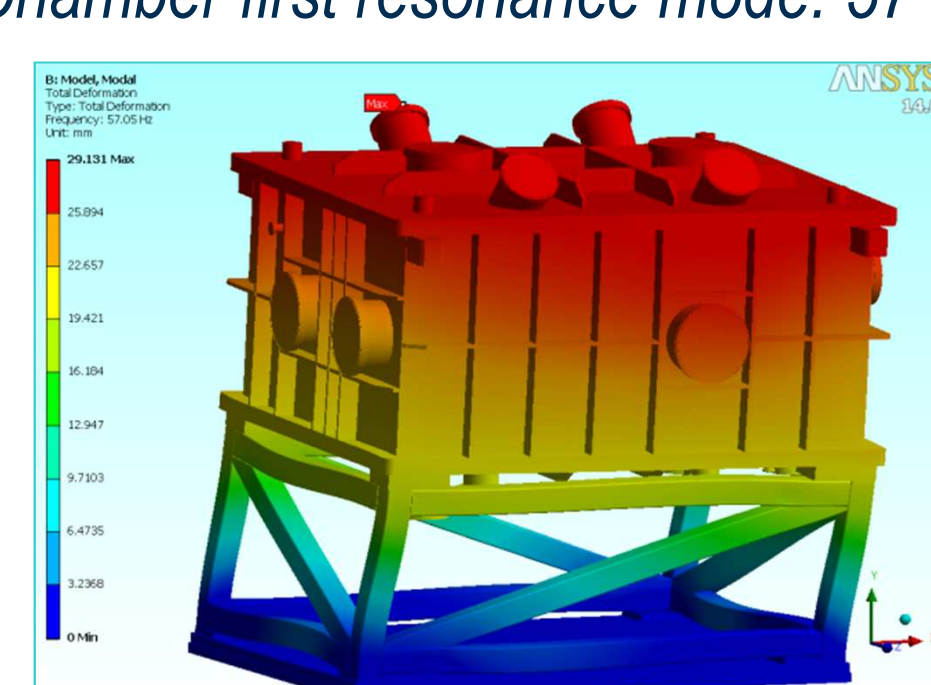


- Maximum viewports deviation: $0,34 \mu\text{rad}$

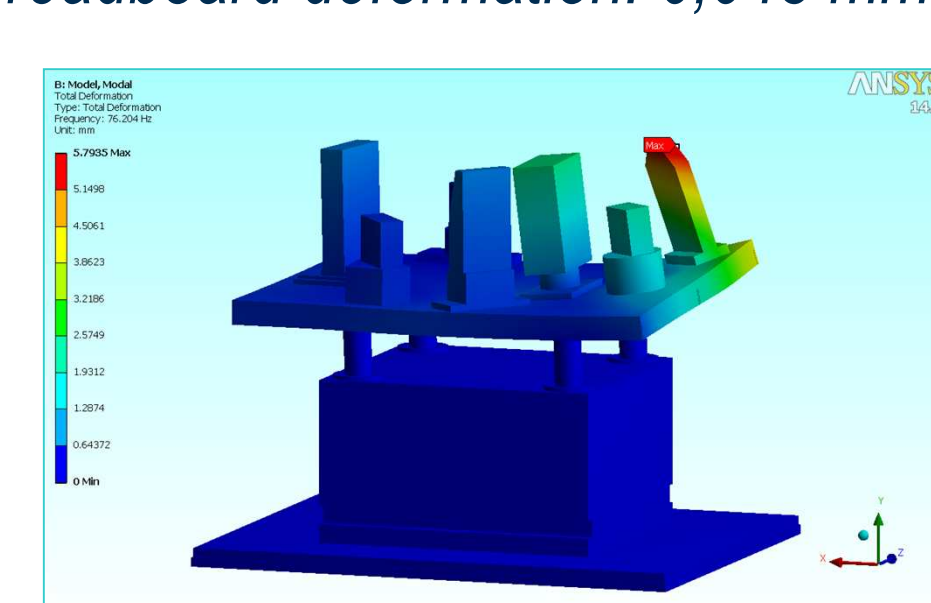


Breadboard Stability

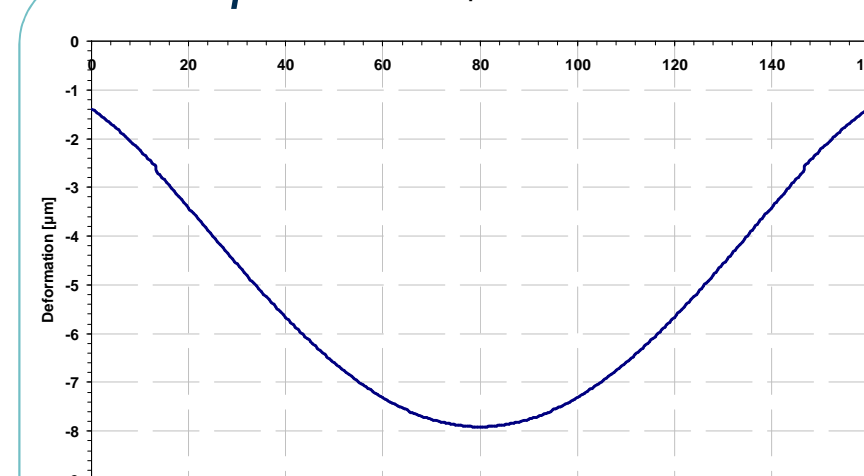
- Chamber first resonance mode: 57 Hz.



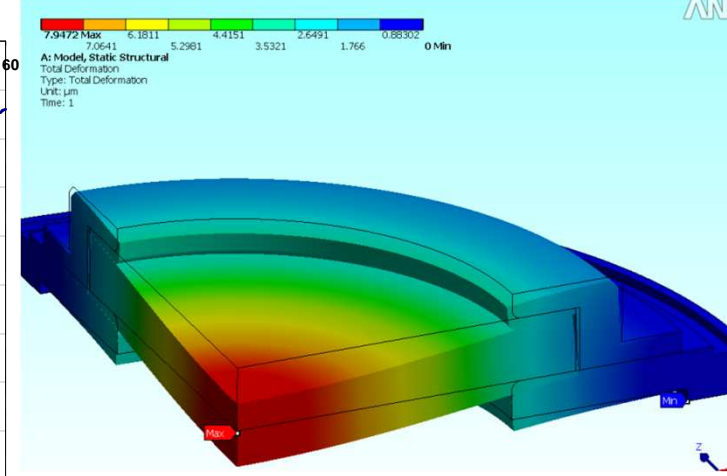
- Breadboard first resonance mode: 43,6 Hz.
- Breadboard deformation: 0,043 mm



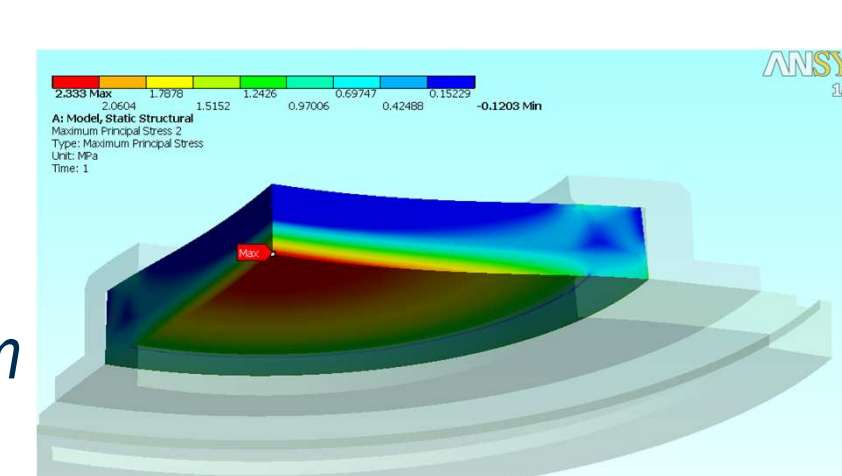
Viewport



Maximum glass deformation: $7,94 \mu\text{m}$.

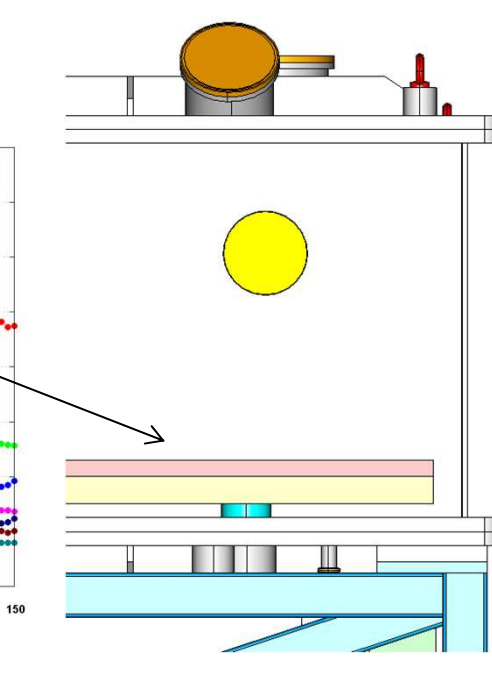
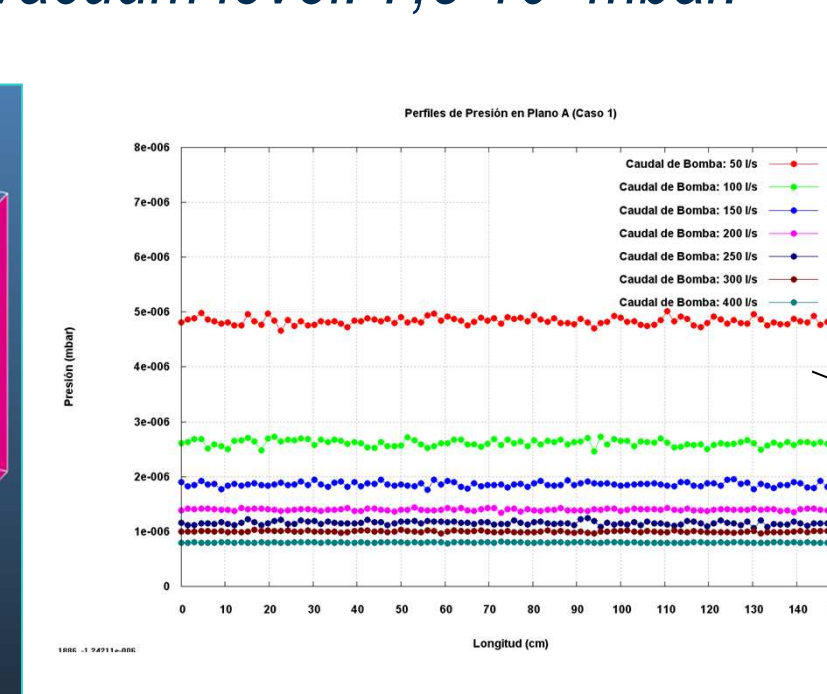
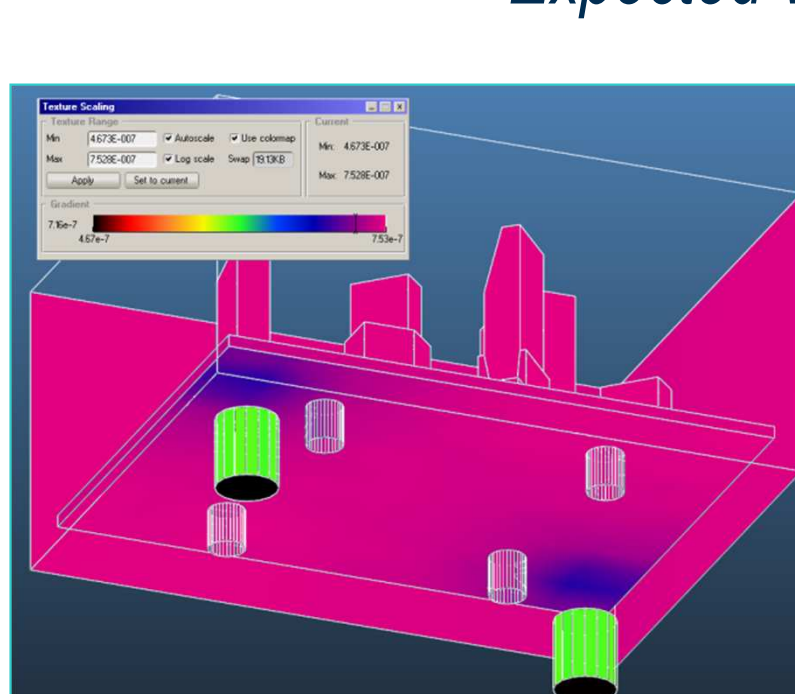


- Material: BK7, Borosilicate
- Maximum stress: 2,8 MPa.
- Tensile strength: 6,9 MPa.
- Glass displacement: 2,5 mm



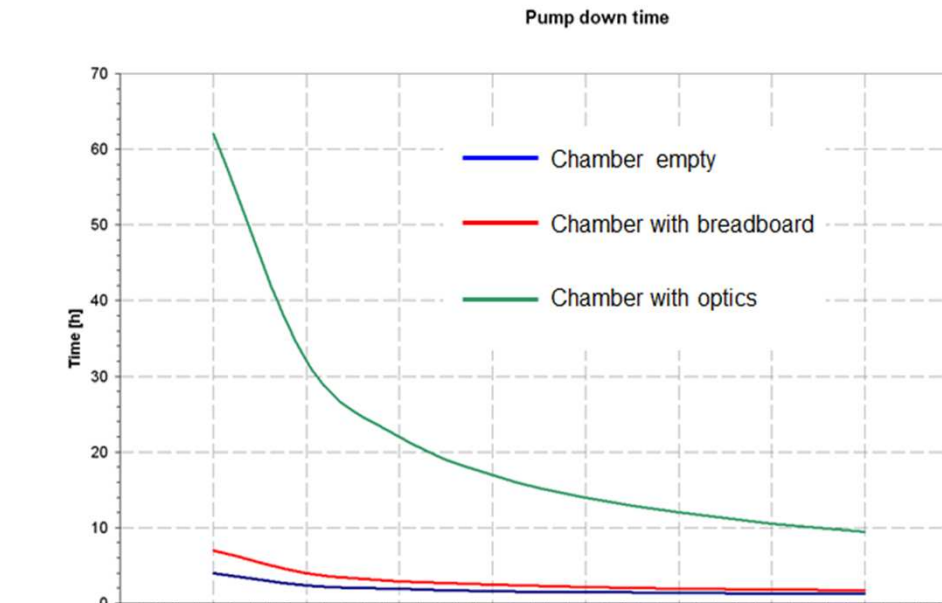
Vacuum

- Calculations analytically and with Molflow+
- Expected vacuum level: $7,5 \cdot 10^{-7}$ mbar.



Pumping Down time (10^{-6} mbar): $< 10\text{h}$.

$$t = \frac{V}{S_{\text{effective}}} \ln \left(\frac{P_i}{P_f} \right)$$



Construction & tests

Vacuum chamber

Characteristic	Expected, FEA	Tested
Wall	0,12 mm	0,13 mm
Bottom cap	0,814 to 0,712mm	0,760 mm

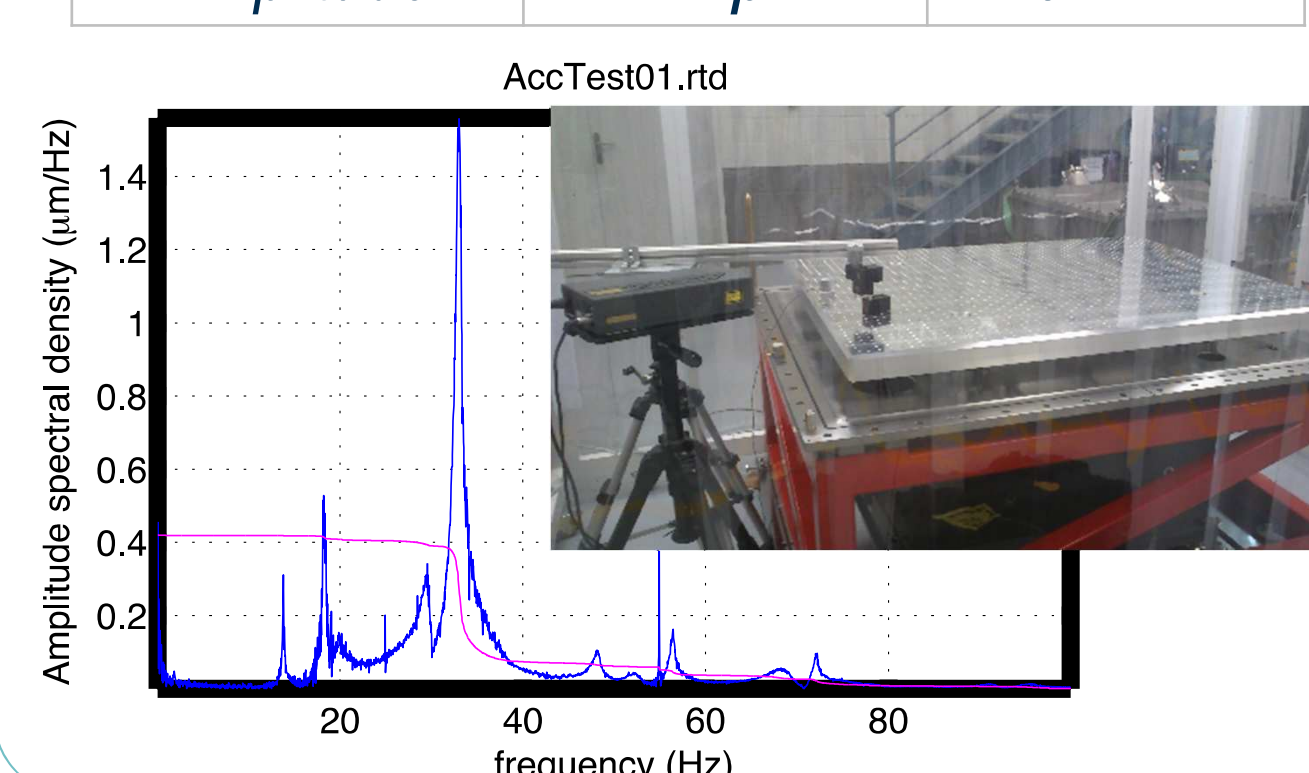


Factory acceptance Tests

- A prototype of the view port
- Vacuum chamber wall deformation
- Vacuum level and pumping down time
- Vibrations without epoxy glue.

Breadboard Stability

Characteristic	Calculated	Tested
1st mode	0.56Hz	-
2nd mode	34 Hz	33 Hz
3rd mode	42 Hz	-
Amplitude	$< 1 \mu\text{m}$	52 nm



Viewport



Characteristic	Performance
Vacuum level	$5,7 \cdot 10^{-7}$ mbar
Leak background	10^{-9} mbar-l/s
Glass vacuum displacement	0,2 mm

Vacuum

Characteristic	Calculated	Tested
Ultimate pressure	$7,5 \cdot 10^{-7}$ mbar	$3,6 \cdot 10^{-7}$ mbar
Pumping time up to $5 \cdot 10^{-6}$ mbar	$< 10\text{h}$	2,5 h
Leak detection	$2,27 \cdot 10^{-9}$ mbar-l/s	10^{-9} mbar-l/s

